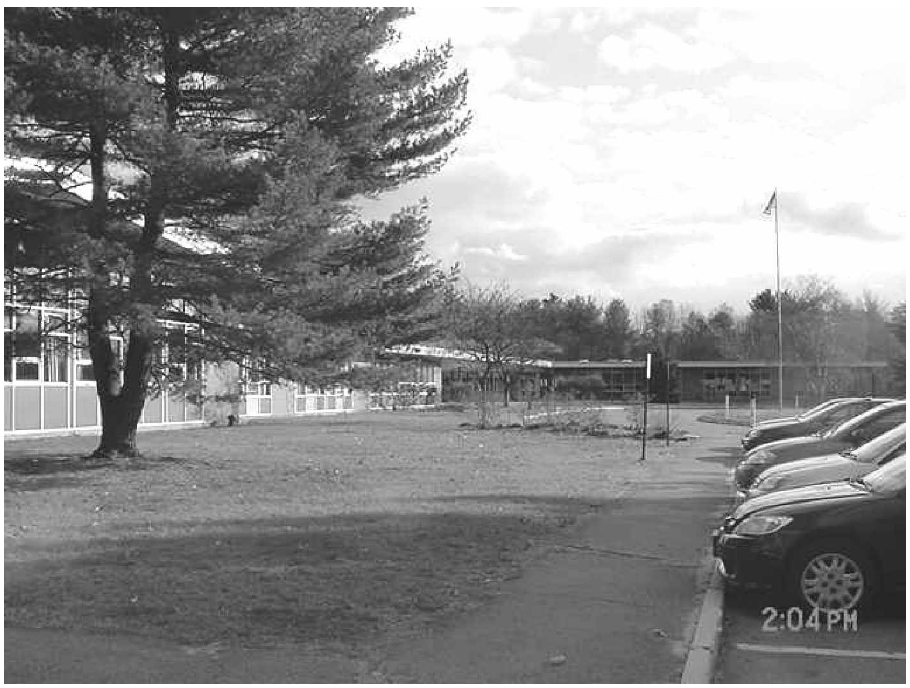
INDOOR AIR QUALITY ASSESSMENT

Joseph Estabrook School
117 Grove Street
Lexington, MA 02420



Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of parents, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality (IAQ) concerns at the Joseph Estabrook School (JES) in Lexington, Massachusetts. The IAQ assessment was prompted by reports of poor ventilation, general indoor air quality complaints and chronic roof leaks.

On December 2, 2005, a visit to conduct an indoor air quality assessment was made to this school by Cory Holmes, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. During the assessment, Mr. Holmes was accompanied by Joe McGauhlin, Custodian, JES, and Derrick Fullerton, Director of the Lexington Health Department. Mr. Holmes also met with Bill Hartigan, Director of Facilities for Lexington Public Schools (LPS), and Joni Jay, JES Principal, prior to the assessment.

The JES is a one-story red brick building constructed in the late 1950s. Two general classrooms were added at an unknown date, but appear to be 1960s-1970s vintage. Modular classrooms were reportedly added in the mid-1990s. As previously mentioned, the building has a history of roof leaks. School officials reported that major sections of the roof were replaced over the summer of 2005. In addition, water damaged ceiling tiles were replaced. No further leaks were reported by school officials, maintenance staff or building occupants since the repairs.

To address mold growth concerns, the LPS hired an environmental engineering firm, ATC Associates, Inc., to conduct a microbial investigation in August of 2005. The ATC report found that indoor mold levels were lower than those found outdoors and that indoor mold species were similar to those found outdoors. ATC recommended that: (1) water stained ceiling/missing tiles be replaced; (2) any possible moisture intrusion be monitored and repaired; (3) blockages to classroom exhaust vents be removed, and (4) a full inspection and cleaning of HVAC ducts and mechanical equipment be performed in accordance with published standards of the national Air Duct Cleaners Association (ATC, 2005).

Prior to the MDPH assessment, Mr. Hartigan reported that the LPS is undertaking an aggressive campaign to assess current conditions and needs for repairs to mechanical ventilation systems in each of Lexington's public schools. In November of 2005, a comprehensive evaluation of heating and ventilation systems was conducted throughout the JES by Timothy J. O'Leary of The Building Doctor Inc., an HVAC engineering firm. Mr. O'Leary provided the LPS with a detailed analysis of the functionality of all heating and ventilation equipment. Mr. Hartigan reported that the LPS planned to use Mr. O'Leary's report to address mechanical ventilation needs. In a subsequent conversation with Mr. Hartigan on January 18, 2006, he reported that the LPS was preparing a request for proposal to make repairs.

The school contains general classrooms, music room, specialty learning rooms, gymnasium, library, art room and office space. The school has no working cafeteria; children eat at tables set up in the main hallway. As previously mentioned, the roof was replaced over the summer of 2005, all other major structural aspects or equipment in the school appeared to be original (e.g., floors, plumbing, mechanical ventilation equipment, windows). Windows throughout the building are openable.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™

Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The JES houses approximately 480 kindergarten through fifth grade students with approximately 35 staff members. Tests were taken during normal operations at the school and results appear in Table 1.

Discussion

Ventilation

As discussed, a comprehensive analysis to evaluate mechanical heating and ventilation components at the JES was conducted in November of 2005. At the time of MDPH's early December assessment, Mr. Hartigan reported that twenty of twenty-five unit ventilators (univents) were inoperable and that five of fifteen rooftop exhaust vents were inoperable. Without adequate supply and exhaust ventilation, excess heat and environmental pollutants can build up and lead to indoor air/comfort complaints.

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in seventeen of twenty-five areas, indicating inadequate ventilation in the majority of areas surveyed, mainly due to mechanical ventilation components inoperable or deactivated. It is also important to note that areas with carbon dioxide levels below 800 ppm were sparsely populated, unoccupied and/or had windows open, which can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to be higher with full occupancy when exterior doors and windows are shut.

As mentioned, fresh air in the majority of classrooms is supplied by a unit ventilator (univent) system (Picture 1). A univent draws air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 2) and returns air through an air intake located at the base of the unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. Univents are equipped with control settings of low, medium or high (Picture 3). Although the majority of univents were inoperable at the time of the assessment, those that were operable were deactivated. Obstructions to airflow, such as papers and books stored on univents and items in front of univent returns were seen in a number of classrooms (Pictures 1, 4 and 5). In order for univents to provide fresh air as designed, air diffusers and return vents must remain free of obstructions. Importantly, these units must remain "on" and allowed to operate while rooms are occupied.

Exhaust ventilation is provided by grated wall vents ducted to rooftop motors. As with the univents, these vents were not drawing air and/or were obstructed in several areas (Picture 6/Table 1). Exhaust vents must be activated and remain free of obstructions to function as designed.

Mechanical ventilation in classrooms 6 and 20 is provided by an air handling unit (AHU) located in the basement (Picture 7). Fresh air is drawn through an outside air intake, heated, filtered and distributed to classrooms via ceiling-mounted air diffusers (Picture 8). Return air is drawn into grated wall vents back to the AHU (Picture 8). The AHU was not operating during the assessment. Mechanical ventilation for the gym is provided by AHUs in mechanical rooms.

These AHUs were also inoperable at the time of the assessment as indicated by elevated carbon dioxide levels that were measured in the gym (1,035 ppm).

Ventilation for modular classrooms is provided by rooftop AHUs (Picture 9). Fresh air is distributed to classrooms via ductwork connected to ceiling-mounted air diffusers. Return vents draw air back to the units through ceiling-mounted grilles. Thermostats control each heating, ventilating and air conditioning (HVAC) system and have fan settings of “on” and “automatic”. Thermostats were set to the “automatic” setting (Picture 10) in all of the modular rooms surveyed during the assessment. The automatic setting on the thermostat activates the HVAC system at a preset temperature. Once the preset temperature is reached, the HVAC system is deactivated. Therefore, no mechanical ventilation is provided until the thermostat re-activates the system.

A series of small offices/special education rooms were constructed in the hallway. The offices are equipped with wall-mounted exhaust vents but have no provision for supply air. It is recommended that passive door vents be installed to provide make up air (Picture 11).

In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment. In their current condition, mechanical ventilations systems cannot be balanced until repairs are made.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room

(SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings on the assessment day were measured in a range of 70 ^{o} F to 78 ^{o} F, which were within the MDPH comfort guidelines. The MDPH recommends that indoor air temperatures be maintained in a range between 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. Although these measurements were within guidelines during the assessment, a number of temperature control complaints were reported. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents and exhaust vents not operating/obstructed).

Relative humidity measurements ranged from 26 to 41 percent, which were below or at/near the lower level of the MDPH comfort range. The MDPH recommends that indoor air relative humidity be maintained in a comfort range of 40 to 60 percent. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

As discussed, the building has a history of roof leaks and water damage. New roofs were installed during the summer of 2005 and water damaged ceiling tiles were replaced; however, a few water damaged ceiling tiles were observed in some areas (Table 1). Water damaged ceiling tiles can provide a source of mold growth and should be replaced after a water leak is discovered and repaired.

Steam leaks from heating pipes were noted in rooms 3, 20 and 22. In classroom 3 the carpeting around the univent was wet. JES staff was aware of the leak in classroom 3, and deactivated the univent at the time of assessment. CEH staff recommended that the carpeting be dried with fans. In classrooms 20 and 22, the leaks were inside a radiator (Picture 12) and a univent, respectively. These leaks were reported to Mr. Hartigan during the assessment. MDPH staff recommended that once repairs were made, the carpeting in classroom 3 be dried (e.g., fans and/or heating) and the interior of the radiator casing in classroom 20 and univent in classroom 22 be cleaned and dried to prevent microbial growth.

Spaces between the sink countertop and backsplash were noted in several classrooms (Table 1). Improper drainage or sink overflow can lead to water penetration of countertop wood, the cabinet interior and behind cabinets. Like other porous materials, if these materials become wet repeatedly they can provide a medium for mold growth.

The US Environmental Protection Agency and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

In several areas around the building, trees and shrubbery were observed growing against or in close proximity to exterior walls and over the roof (Pictures 13 through 15). The growth of plants/roots against the exterior walls and along the foundation can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level. Clinging plants inserting tendrils into brick and mortar can cause water damage to brickwork. Water can penetrate into the brick along the tendrils, which can subsequently freeze and thaw during the winter. This freezing/thawing action can weaken bricks and mortar, resulting in wall damage.

A grated subterranean pit was observed on the exterior of the building, which allows air to flow below grade into the air intake for the AHU in the basement mechanical room. Leaves, papers and other debris were observed on the floor of these pits (Picture 16). Such debris can provide a source of mold growth and should be cleaned periodically.

Plants were noted in several classrooms. Plants can be a source of pollen and mold, which can be respiratory irritants for some individuals. Plants should be properly maintained and equipped with drip pans. Plants should also be located away from univents to prevent the aerosolization of dirt, pollen or mold.

A number of aquariums were located in classrooms. Aquariums should be properly maintained to prevent microbial/algae growth, which can emit unpleasant odors. Similarly, terrariums should be properly maintained to ensure soil does not become a source for mold growth.

Other IAQ Evaluations

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, CEH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. For the JES, indoor carbon monoxide concentrations were non-detectable (ND). Carbon monoxide levels measured outdoors were also ND (Table 1).

As discussed, the US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average. This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average. Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, CEH uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations the day of the assessment were measured at 15 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors ranged from 7 to 54 $\mu g/m^3$, which were below the NAAQS of 65 $\mu g/m^3$ (Table 1). Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system; cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Indoor TVOC concentrations throughout the building were ND. Outdoor TVOC measurements were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While TVOC levels were ND, materials containing VOCs were present in the school. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Cleaning products and other chemicals were found in floor level cabinets and on counter tops in several classrooms (Picture 17). VOC-containing cleaning products, such as bleach or ammonia-related compounds, contain chemicals that can be irritating to the eyes, nose and throat. These items should be stored properly and out of the reach of students.

Several other conditions that can affect indoor air quality were noted during the assessment. In a number of classrooms, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Stuffed pillows/toys were noted in some classrooms (Picture 18). Stuffed toys used by an individual child should be washed on a weekly basis (Hale and Polder, 1996). Furthermore, stuff pillows/toys can be a point for dust collection. Close contact with such items can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. As discussed, dust can be irritating to the eyes, nose and respiratory system.

Items were also observed hanging from ceiling tiles in some classrooms. Movement of or damage to ceiling tiles can release accumulated dirt, dust and particulates accumulated in the ceiling plenum into occupied areas. The blades of personal fans were also noted with accumulated dust. Dust and materials can be aerosolized when the fans are activated. As previously discussed, dust can be irritating to the eyes, nose and respiratory tract. Building occupants should refrain from hanging objects from ceiling tile systems. Fans should also be cleaned periodically to prevent dust accumulation on fan blades.

An inactive birds' nest that reportedly serves as a learning prop was seen in a classroom. Birds' nests can contain bacteria and may also be a source of allergenic material. Nests should be placed in resealable bags to prevent aerosolization of allergenic material. These items should also be located away from fresh air diffusers of univents.

Lastly, in an effort to reduce noise from sliding chairs, tennis balls had been spliced open and placed on chair legs (Picture 19). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off gas VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998b).

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Continue with plans to make repairs to mechanical heating and ventilation equipment building wide.
2. Once repairs are made operate all functional ventilation systems throughout the building (e.g., gym, cafeteria, classrooms) continuously during periods of school occupancy and independent of thermostat control. To increase airflow in classrooms, set univent controls to “high”.
3. Use openable windows in conjunction with classroom univents and exhaust vents to create air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
4. Set thermostats for modular classrooms to the fan “on” position to operate the ventilation system continuously during the school day.
5. Inspect exhaust motors and belts for proper function. Repair and replace as necessary.
6. Remove all blockages in classrooms from univents and exhaust vents to ensure adequate airflow.
7. Install a passive vent in the door of hallway offices/special education rooms to provide air exchange.
8. Consider adopting a balancing schedule of every 5 years for mechanical ventilation systems, as recommended by ventilation industrial standards (SMACNA, 1994).
9. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to

minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

10. Ensure steam leaks are repaired in heating system. Inspect carpeting and other porous materials in these areas (classrooms 3, 20 and 22) for mold growth. If moldy, replace affected materials, clean and disinfect non-porous materials with an appropriate antimicrobial.
11. Replace water-damaged ceiling tiles. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
12. Remove shrubbery away from contact with exterior walls.
13. Remove leaves and debris from subterranean pits seasonally.
14. Move plants away from univents in classrooms. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary. Consider reducing the number of plants in some areas.
15. Vacuum interior of univents during regular filter changes to prevent the accumulation/aerosolization of dirt, dust and particulates.
16. Clean accumulated dust from blades of personal fans and exhaust vents on a regular basis.
17. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.

18. Store cleaning products properly and out of reach of students.

19. Refrain from hanging items from ceiling tile systems.

20. Wash stuffed toys/pillows often to prevent spread of disease and respiratory irritants.

21. Consider discontinuing the use of tennis balls on chair legs to prevent latex dust generation. Alternative “glides” can commonly be purchased from office supply stores (see Picture 20 for an example).

22. Consider adopting the US EPA document (2000b), *Tools for Schools*, to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.

23. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are available from the MDPH’s website: http://mass.gov/dph/indoor_air.

References

ACGIH. 1989. Guidelines for the Assessment of Bioaerosols in the Indoor Environment. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989

ATC. 2005. ATC Associates, Inc. Limited Microbial Investigation Report, Estabrook Elementary School, ATC Project No.: 60.13806.0017, Dated September 21, 2005

BOCA. 1993. The BOCA National Mechanical Code/1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL.

Hale, C.M., Polder, J.A. 1996. *The ABC's of Safe and Healthy Child Care a Handbook for Child Care Providers,* Department of Health and Human Services. United States Public Health Service, Centers for Disease Control

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

NIOSH. 1997. NIOSH Alert Preventing Allergic Reactions to Natural Rubber latex in the Workplace. National Institute for Occupational Safety and Health, Atlanta, GA.

NIOSH. 1998. Latex Allergy A Prevention. National Institute for Occupational Safety and Health, Atlanta, GA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation. Bellwood, IL.

SBAA. 2001. Latex In the Home And Community Updated Spring 2001. Spina Bifida Association of America, Washington, DC.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0.

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

US EPA. 2000a. National Ambient Air Quality Standards (NAAQS). . US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC. http://www.epa.gov/air/criteria.html.

US EPA. 2000b. Tools for Schools. Office of Air and Radiation, Office of Radiation and Indoor Air, Indoor Environments Division (6609J). EPA 402-K-95-001, Second Edition. http://www.epa.gov/iaq/schools/tools4s2.html

US EPA. 2001. Mold Remediation in Schools and Commercial Buildings. US Environmental Protection Agency, Office of Air and Radiation, Indoor Environments Division, Washington, D.C. EPA 402-K-01-001. March 2001.

Picture 1

Classroom Univent, Note Items on Top of Air Diffuser

Picture 2

Univent Fresh Air intake

Picture 3

Univent Control Settings, Note Unit is Deactivated Via the Toggle Switch

Picture 4

Table and File Cabinets in Front of Univent Obstructing Return Vent
(along bottom front of unit)

Picture 5

Items on and in Front of Univent Obstructing Airflow

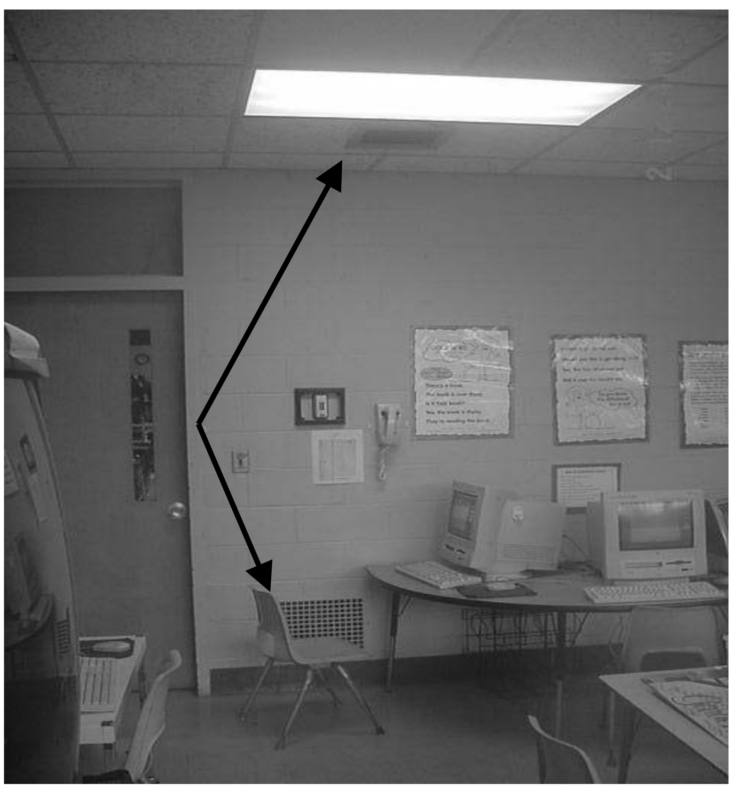
Picture 6

Classroom Exhaust Vent Obstructed by Computer Table

Picture 7

Air Handling Unit in Basement

Picture 8



Ceiling-Mounted Air Diffuser and Wall-Mounted Return Vent (Classrooms 6 and 20)

Picture 9

Rooftop AHU for Modular Classroom

Picture 10

Thermostat for Modular Classroom

Picture 11

Example of Passive Vent Recommended for Small Offices/Special Learning Areas Constructed in Hallway (e.g., Ms. Zendeh's Room)

Picture 12

Steam Leak inside Radiator Unit in Classroom 20

Picture 13

Trees/Shrubbery Growing against Exterior Wall in Courtyard

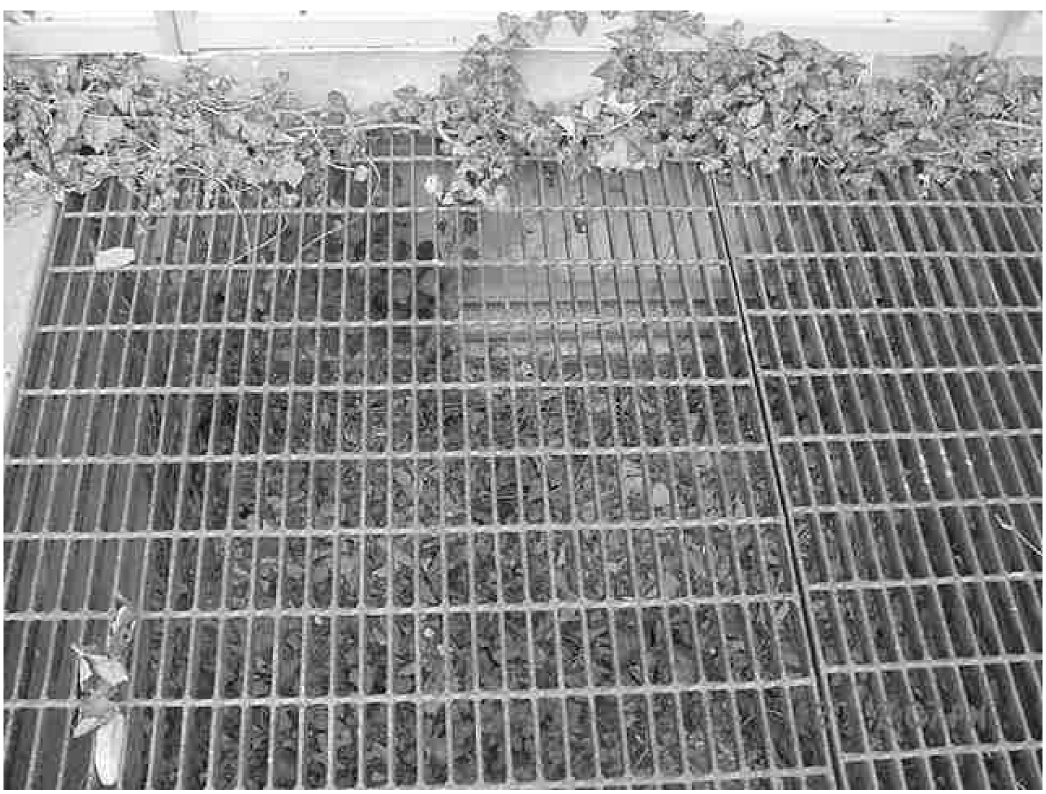
Picture 14

Trees Growing against Exterior Wall

Picture 15

Trees Overhanging Roof

Picture 16



Leaves/Plant Debris in Subterranean Air Intake for Basement AHU

Picture 17

Spray Cleaning Products under Classroom Sink

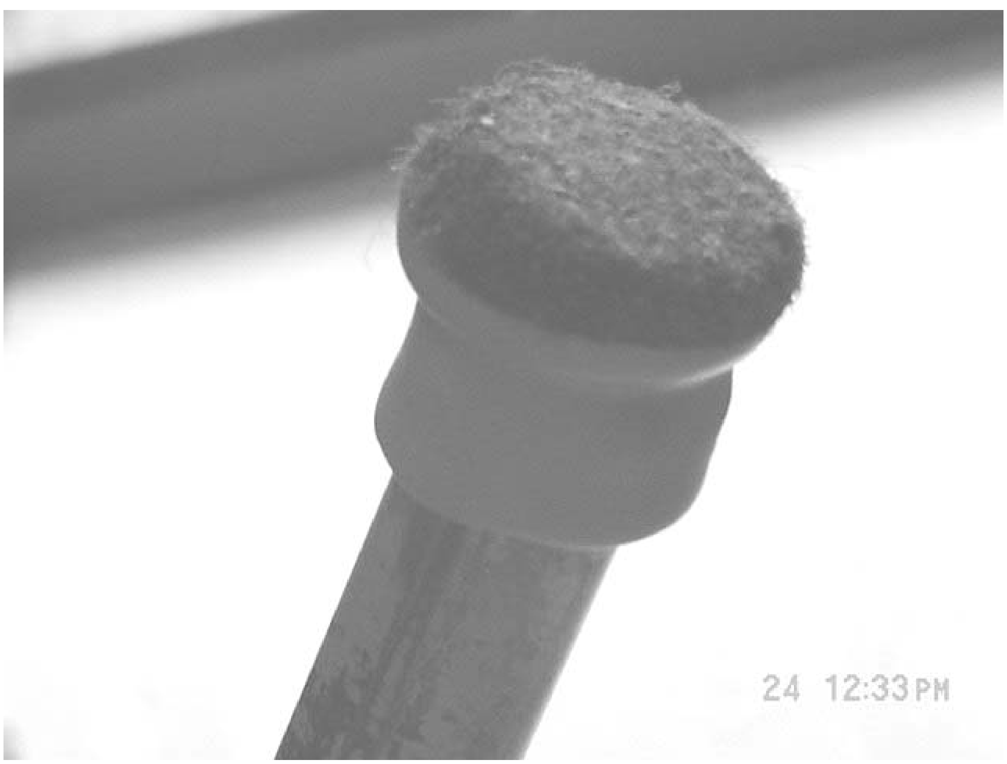
Picture 18

Stuffed Toys and Pillows on Classroom Floor

Picture 19

Tennis Balls on Chair Legs

Picture 20



“Glides” for Chair Legs that can be used as an Alternative to Tennis Balls

Joseph Estabrook School

117 Grove Street, Lexington, MA 02420

Table 1

Indoor Air Results

Date: 12/2/2005

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background	0	50	40	420	ND	ND	15	N			Cold, cloudy, NE winds 10-15, gusts up to 20 mph.
basement	0	74	29	562	ND	ND	16	N			AHU not operating, holes in unit, IPM traps on floor.
39-C	3	73	34	895	ND	ND	21	Y # open: 0 # total: 2	Y univent (off) plant(s)	Y wall items furniture	Hallway DO, #WD-CT: 1, temperature complaints (hot), 21 occupants gone approx 10 min.
gym	15	72	35	1035	ND	ND	54	Y # open: 0 # total: 6	Y (off)	Y (off)	Hallway DO, 2 AHU in mech room need parts.
2-A	12	72	35	1259	ND	ND	17	N	Y univent (off) items furniture	Y (off) furniture	breach sink/counter, cleaners.
1-A	17	73	38	1373	ND	ND	180	Y # open: 0 # total: 0	Y (off) items	Y wall (off)	Hallway DO, breach sink/counter, cleaners, items.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Joseph Estabrook School **Indoor Air Results**

117 Grove Street, Lexington, MA 02420 **Table 1** **Date: 12/2/2005**

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
3	15	73	32	708	ND	ND	11	Y # open: 1 # total: 2	Y univent (off)	Y wall (off)	Hallway DO, WD-carpet, #WD-CT: 5, breach sink/counter, PF, aqua/terra, cleaners, items, nests, plants, steam leak in UV, rec drying carpet with fans/heat.
4	18	73	36	1112	ND	ND	21	N	Y univent (off)	Y wall (off)	PF, items.
5	19	77	40	1170	ND	ND	19	Y # open: 0 # total: 2	Y univent	Y wall (off)	Hallway DO, DEM, PF, cleaners, items.
6	1	74	36	674	ND	ND	10	Y # open: 0 # total: 2	Y ceiling (off)	Y wall (off)	Hallway DO, breach sink/counter, DEM, cleaners, 16 occupants gone 20 mins .
7A-Modular	0	72	34	1014	ND	ND	11	Y # open: 0 # total: 0	Y ceiling (off)	Y ceiling (off)	#WD-CT: 1, plants, 20 occupants gone 10 mins, themostat fan "auto", condensation on window pane.

ppm = parts per million
µg/m3 = micrograms per cubic meter

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aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
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									Supply	Exhaust	
7B-Modular	20	72	31	863	ND	ND	18	Y # open: 0 # total: 2	Y ceiling	Y ceiling	Hallway DO, TB, thermostat fan "auto".
7C-Modular	22	71	31	840	ND	ND	8	Y # open: 0 # total: 2	Y ceiling	Y ceiling	CD, space under exterior door.
8-B	18	73	34	804	ND	ND	12	Y # open: 0 # total: 2	Y ceiling	Y ceiling (off)	Hallway DO, floor pillows.
11	18	76	34	1083	ND	ND	20	Y # open: 0 # total: 2	Y univent (off) items	Y wall furniture	Hallway DO,
13	0	74	41	502	ND	ND	10	Y # open: 1 # total: 2	Y univent (off)	Y wall	plants.
19	0	72	26	542	ND	ND	7	Y # open: 0 # total: 2	Y univent	Y wall furniture	Hallway DO, PF, plants.

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									Supply	Exhaust	
20	21	73	38	1198	ND	ND	13	Y # open: 0 # total: 2	Y ceiling (weak)	Y wall items	#WD-CT: 2, cleaners, hissing radiator (right) moisture in unit.
21-A	2	78	27	736	ND	ND	16	Y # open: 0 # total: 0	Y univent (off)	Y wall	
21-B	3	73	27	716	ND	ND	12	Y # open: 0 # total: 1	Y wall		Hallway DO, PF.
22	28	72	34	1045	ND	ND	14	Y # open: 0 # total: 2	Y univent	Y wall	Hallway DO, DEM, PF, items hanging from CT, plants, hissing UV.
23	24	75	32	1029	ND	ND	8	Y # open: 0 # total: 2	Y univent (off)	Y wall	DEM, PF.
24-A	0	70	31	1105	ND	ND	13	Y # open: 0 # total: 0	Y univent	Y wall	Hallway DO, PF, aqua/terra, plants.
25-A	0	72	31	958	ND	ND	10	Y # open: 1 # total: 2	Y univent (off)	Y wall (weak)	

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									Supply	Exhaust	
26	23	73	33	1153	ND	ND	21	N	Y univent items furniture	Y ceiling (off)	Hallway DO, DEM, PF.
27	23	72	27	709	ND	ND	13	Y # open: 1 # total: 2	Y univent items furniture	Y (off)	Hallway DO, PF.
Zendeh	2	71	28	703	ND	ND	13	N	N	Y ceiling	Hallway DO, DEM, PF, recommend passive vent in door (supply).

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